

***Crossata* (Gastropoda: Bursidae) in the eastern Pacific: A morphologic and paleontologic perspective**

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ABSTRACT An examination of numerous specimens of the bursid genus *Crossata*, found in museum and private collections, lead us to conclude that *C. californica* (Hinds, 1843) and *C. ventricosa* (Broderip, 1833) are separate species, geographically isolated from one another and are morphologically distinct. This differs from the current widely held view that they represent a single, wide ranging and extremely variable species occurring from southern California to Chile. *Crossata californica* ranges from southern California to Baja California, with an isolated relic population in the Gulfo de California. *Crossata ventricosa* which appears to be a species complex, ranges from southern Ecuador through Peru, and rarely into northern Chile, although with further study the latter may be found to represent a new species. A new species *Crossata barbarajeanae* n. sp. is described from specimens previously assigned to *C. ventricosa* from the vicinity of Bahia de la Independencia, Peru.

KEYWORDS Bursidae, *Crossata*, *Crossata californica*, *Crossata ventricosa*, morphology, biogeography, paleontology

INTRODUCTION

It was suggested over 20 years ago (Cossignani, 1993) that *Crossata californica* (Hinds, 1843), the California Frog Shell, be synonymized with *C. ventricosa* (Broderip, 1833) a Peruvian Province species, but only formalized by Beu (2010) seven years ago. In some circles, there is considerable debate over changing the name of the northern hemisphere material to *C. ventricosa* and, we believe, this change warrants further investigation. The ICZN principle of priority set forth in Article 23 states that "the valid name of a taxon is the oldest available name applied to it, unless that name has been invalidated or another name is given precedence by any provision of the Code" (ICZN Article 23.1) Thus, Broderip's name has priority if the populations of of *C. californica*

and *C. ventricosa* constitute the same species. This begs the question of whether they are the same species and whether Beu's synonymy should be accepted.

The first publication to suggest synonymizing *Crossata californica* with *C. ventricosa* was the popular book "Bursidae of the World" by Tiziano Cossignani (1994). Cossignani gave the geographic range of *C. ventricosa* as Ecuador to Chile, and the geographic range of *C. californica* as California. Cossignani (1994, p. 95) stated that: "The naming of this species is essentially based on geographic reasons. ... It is not to be excluded that *C. californica* might become a subspecies or even a form of *C. ventricosa*, an earlier taxon." There was no serious discussion nor analysis to support Cossignani's (1994) opinion that the similarities

between these two species were enough to synonymize them. Shortly thereafter, Cossignani's opinion on the validity of *C. californica* was supported by Von Manfred Parth (1996), without analysis. Similarly, Parth (1996) was cited in Beu (2001) as the basis for referring *C. californica* (Hinds, 1843) and *C. ventricosa* as one intergrading species whose geographic range is "from southern California to Peru and perhaps northern Chile" (Beu, 2001).

Subsequently, Beu (2010) suggested that *Bursa calcipicta* Dall, 1908 is an offshore deep water juvenile form of *C. ventricosa* that "link the two populations of larger adults." Beu (2010, p. 71) also stated that "this ... appears to be a single clinally varying species with adults in relatively cool northern and southern waters, linked through the tropical eastern Pacific by planktonic larvae and a few small specimens that manage to survive in offshore waters, although apparently not reaching breeding size." (*Id.*)

Unfortunately none of these publications discuss, compare, or analyze the morphology, ecology, biogeography, or fossil history of these three species. We dispute Beu's (2010) conclusion that *Crossata ventricosa* (Broderip, 1833) is a single variable species ranging from Monterey, California, USA, to northern Chile.

Abbreviations used and collections examined:

ABC = Andre Bonard collection
 CAS = California Academy of Sciences
 DBC = David P. Berschauer collection
 FEM = Femorale, courtesy of Marcus Coltro
 LACM = Natural History Museum of Los Angeles County
 PKC = Paul Kanner collection
 SBMNH = Santa Barbara Museum of Natural History

METHODS

Specimens of *Crossata californica*, *C. sonora*, *C. ventricosa*, and *Bursa calcipicta* with reliable locality data from museum and private collections in California were examined, and many specimens measured and photographed. Locality data was used to determine in which molluscan biogeographic provinces the various species reside. Finally, a literature search was conducted of fossil occurrences of the *Crossata* and the *Bursa* species discussed. Species are listed below in the order they were described (oldest to youngest), by genus.

SYSTEMATICS

Phylum Mollusca Linnaeus, 1758
 Class Gastropoda Cuvier, 1795
 Order Littorinimorpha Golikov and Starobogatov, 1975
 Superfamily Tonnoidea Suter, 1913
 Family Bursidae Thiele, 1925
 Genus *Crossata* Josseume, 1881

Crossata ventricosa (Broderip, 1833)

Figures 1, 6C-D, 8B, 10A-H and J-K, 11A-D

Geographic range: Peruvian Province. Warm temperate zone. According to the literature, the species is found south of the Gulf of Guayaquil, Ecuador in the north through Peru, and rarely into northern Chile, although the Chilean occurrences may represent a new undescribed species. Specimens are known to have been collected from 15 to 170 m water depth. We were unable to find any records of this species being collected in either Ecuador or Chile..

Fossil occurrences:

Miocene: Specimens reported from the Tumbes sandstone, Que. Tucillal at Zorritos, Peru (Olsson, 1932) are heavier and more strongly sculptured than modern *C. ventricosa* (Olsson,

1932, pl. 21, fig. 1) and resemble *C. californica* but have fewer nodes on the body whorl. We assume Olsson's (1932) publication may be part of the reason Beu (2010) concluded that *C. ventricosa* and *C. californica* are synonyms. However, these fossil specimens differ from living *C. ventricosa* and should be described as a new species. Given this, we find no Miocene occurrences of this species.

Pliocene: Canoa Formation, Ecuador (Pilsbry and Olsson, 1941), Esmeraldas Formation, Ecuador (Jung, 1989), Onzole Formation, Ecuador (Landau and Marques da Silva, 2010), Shark Hole Formation, Panama (Collins and Coates, 1999; Beu, 2010) this occurrence seems outside of the temperature zone where this species has occurred and needs verification, and Taie Formation, Peru (DeVries, 1988).

Pleistocene: San Juan Terrace, Peru (Ortlieb and others, 1990), Caleta Patillos, Chile (Rivadeneira and Carmona, 2008).

Size: Adults range from 55 to 75 mm in length.

Description: A moderate sized thin shell, globose in cross section, typically with a fairly smooth body whorl, bearing 10 to 12 small nodes on the shoulder of the body whorl, a thin to moderate lip forming a weak varix twice per whorl with denticles absent to weak on the inner portion of the outer lip, and with lirae generally absent to weak on the lower portion of the columella. The siphonal canal bends to the right of the longitudinal axis. Spire height appears to be about the same proportion of the entire shell length regardless of size. The shell is tan to medium brown with a white aperture and some specimens bear four to ten dark brown stripes or bands. Specimens from deep water (100 to 170 m) off some of the Peruvian northern offshore islands have shoulder nodes that are somewhat enlarged and form small to medium sharp nodes somewhat resembling *C. californica*.

Discussion: Specimens from deep water found near the northern offshore islands (Isla Lobos de Afuera, Isla Lobos de Tierra, and Isla Macabí) developed shoulder nodes that are generally larger than *C. ventricosa*. They are morphologically distinct from the mainland form and may represent a closely related yet unnamed *Crossata* species (see Figure 10 images C, D, and J). There are also a few specimens reported from Chile that have a parietal shield making them also distinct from both Peruvian forms. It seems likely that *C. ventricosa*, as currently used, represents a complex of species and more study is needed.



Figure 1. *Crossata ventricosa* (Broderip, 1833) 63.1 mm (PKC)

Crossata californica (Hinds, 1844)
Figures 2, 6A-B, 8A, 12A-H, 13A-K

Geographic range: Californian Province. Warm temperate zone. Generally found from Point Conception, California, USA south through Baja California, Mexico. Occasional specimens are found as far north as the Monterey Peninsula, California, USA. There is also a single report from the Kermadec Island, New Zealand (Suter, 1905), however this record is in error. Specimens have been collected from 15 to 30 meters.

There is also a well known geographically isolated population from the Golfo de California taken by shrimp trawlers out of Guaymas, Mexico, which was named *C. sonorana* (Berry, 1960). Some authors consider *C. sonorana* to be a subspecies of *C. californica* (Cossignini, 1994), or a synonym (Parth, 1996; Beu, 2001). We find this species to be morphologically indistinguishable from *C. californica* and consider it synonymous.

Fossil occurrences:

Pliocene: “Fernando” Formation - Brea Canyon, Orange County, CA (Carson, 1925); Los Angeles, Los Angeles County, CA (Davis, 1998); Niguel Formation - Mission Viejo, Orange County, CA (Stadum, 1984); San Diego Formation (Hertlein and Grant, 1960; Albi, 2002; Powell and others, 2009; Vendrasco and others, 2012); “Santa Barbara” Formation - Rincon Point, Santa Barbara/Ventura counties, CA (Powell and others, 2009). Provisionally (*cf.*) identified specimens - location, “Pico” Formation (Powell and others, 2009).

Pleistocene: Lomita Marl - San Pedro, Los Angeles County, CA (Wooding and others, 1946); Palos Verdes Sand - San Pedro, Los Angeles County, CA (Mount, 1970); “San Pedro” Formation - Coyote Hills, Los Angeles/Orange counties, CA (Powell and

Stevens, 2000); Unnamed formations/terraces - Potrero Canyon, Los Angeles County, CA (Woodring *in* Hoots, 1931; Valentine, 1956; Albi, 2002); Isla Coronado, Baja California, Mexico (Durham, 1950); Bahia Tortuga, Baja California, Mexico (Chase, 1956), Rosarito Beach, Baja California, Mexico (Valentine, 1957), Punta Baja, Baja California, Mexico (Emerson and Addicott, 1958); Punta Cabras, Baja California, Mexico (Addicott and Emerson, 1959); San Nicolas Island, Southern California Bight (Vedder and Norris, 1963), Isla Coronados, Baja California, Mexico (Emerson and Hertlein, 1964), Bahia Santa Rosalia quadrangle, Baja California, Mexico (Fife, 1968), San Clemente Island, southern California Bight (Susuki and Stadum, 1978), Isla de Guadalupe, Mexico (Lindberg and others, 1980), Newport Bay, Orange County, CA (Powell and others, 2004).



Figure 2. *Crossata californica* (Hinds, 1844) 97.7 mm (DBC)

Size: Adults range from 60 to 160 mm in length.

Description: A relatively large solid shell, fairly globose in cross section, with spiral sculpture of irregular cords, bearing 6 to 7 large knobs or nodes (which can vary from blunt to sharp) on the shoulder of the body whorl, a heavy thickened apertural lip or varix twice per whorl with heavy denticles, and an inner lip that is expanded into a well defined glossy parietal shield with 10 to 16 well defined lirae crossing the inner lip from the columella. Spire height varies; a higher spire was noted as one of the distinguishing characteristics of *C. sonorana*. Occasionally adult specimens are covered with a white chalky substance termed intriticalx. The shell is cream to light tan in color with a white aperture, and a substantial number of specimens throughout its range bear four thin brown stripes or bands (another of the characteristics of *C. sonorana*).

Crossata sonorana (Berry, 1960)

[synonymized herein with *C. californica* (Hinds, 1844)]

Figures 3, 13L-O

Geographic range: Known only from a relict population in the Cortezian Subprovince of the Panamic Province mostly from shrimp trawls, out of Guaymas, Mexico, presumably at sublittoral water depths. Shrimp boats out of Guaymas usually trawl at 15 to 40 meters water depth (Melzer and others, 2012). Reported once from the Galapagos Islands by Wellington (unpublished, 1975), however according to Finet and others (2014) this record is doubtful.

Fossil occurrences: *Crossata sonorana* has not been reported as a fossil.

Size: Adults range from 60 to 160 mm in length.

Description: A relatively large solid shell, fairly globose in cross section, with spiral

sculpture of irregular cords, bearing 6-7 medium to large sharp knobs or nodes on the shoulder of the body whorl, a heavy thickened apertural lip or varix twice per whorl with heavy denticles, and the inner lip is expanded into a well defined glossy parietal shield with 10 to 16 lirae crossing the inner lip from the columella. Spire height is consistently high compared to *C. californica* from the Californian Province. The shell is cream to light tan in color with a white aperture, bearing four thin brown stripes or bands on the body whorl, intriticalx lacking.



Figure 3. *Crossata sonorana* (Berry, 1960) 103.1 mm (LACM)

Discussion: This species, with its higher spire, sharp shoulder knobs, and four thin brown stripes or bands, is indistinguishable from some forms of *C. californica* along the outer coast of

California and Baja California. Some authors consider *C. sonorana* to be a distinct species (Keen, 1971; Brusca, 1980). However, we conclude that it represents a relic population of *C. californica* left behind in the Golfo de California likely following the last ice age between 20 and 15 thousand years ago when water temperatures were probably between 8° and 10° F cooler than today (Powell, 1994) along the West Coast. At that time the geographic range of *C. californica* likely extended southward to included the Gulf of California. With warming temperatures and rising sea level, this population of *C. californica* became isolated and a restricted gene stock evolved into the population Berry (1960) named *C. sonorana*. While *C. sonorana* is geographically isolated from *C. californica* and may be in the process of speciating, we conclude that some forms of *C. californica* are indistinguishable from *C. sonorana* and it has not become morphologically distinct enough to be considered a separate species.

Crossata barbarajeanae Powell and
Berschauer, n. sp.
Figures 4, 10I, 11E-H

Type Material: The holotype is designated as LACM holotype 3472, from lot number LACM 35-25.1; it is 48.0 mm in length. Figure 10 I depicts apertural, abapertural, and apex views of the holotype. Five paratypes also from lot number LACM 35-25.1, ranging in size from 29.7 to 66.7 mm, are designated as LACM paratype 3473.

Type Locality: The type lot is from Bahia de la Independencia, central Peru, Peruvian Province.

Fossil occurrences: *Crossata barbarajeanae* n. sp. has not been recognized as a fossil.

Size: Adults range from 45 to 70 mm in length.

Diagnosis: *Crossata barbarajeanae* n. sp. can be distinguished from other species in the genus by its nodose sculpture, a siphonal canal that bends slightly to the left of the longitudinal axis (as opposed to the right in *C. ventricosa*), weak lirae on the lower portion of the columella, three nodes on the upper left of the aperture, a rounded anterior siphonal gap (which is pointed in *C. ventricosa*), and a rounded body whorl. *Crossata barbarajeanae* is similar to *C. ventricosa* in that the species does not have a parietal shield that is always found in adult specimens of *C. californica*.



Figure 4. *Crossata barbarajeanae* Powell and Berschauer, n. sp. Holotype, 48.0 mm (LACM 3472)

Description: A moderate sized thin shell, globose in cross section, a rounded body whorl ornamented with fine cords and beads which create a rather delicate pattern, bearing 10 to 12

small nodes on the shoulder of the body whorl, three nodes on the upper left of the aperture, a rounded anterior siphonal gap, a moderate lip forming a definite varix twice per whorl with denticles absent to weak on the inner portion of the outer lip, weak lirae on the columella from near the posterior siphonal notch nearly to the anterior siphonal notch, and three nodes on the upper left of the aperture. The siphonal canal bends slightly to the left of the longitudinal axis. The spire height appears to be fairly consistent. The shell is light tan to light brown with a white aperture and has three to six thin medium to dark brown stripes or bands.

Discussion: The type lot from which the holotype was selected was collected at 9 to 16 meters at Bahía de la Independencia, Ica División, Provincia de Pisco, Peru, by the R/V Velero III in January 1935. Other known specimens were collected along the central coast of Peru in relatively shallow water by local fishermen (M. Coltro (Femorale), personal communication). It is anticipated that more specimens will become available with moderate collecting efforts. In addition to the above type specimens, photographs of four specimens supplied by Marcus Coltro (Femorale) are illustrated in Figure 11 E-H. Unfortunately, these specimens have been distributed to various collections and their whereabouts are unknown.

Etymology: This species is named after the senior author's wife Barbara Jean Powell.

Genus *Bursa* Röding, 1798

Bursa calcipicta Dall, 1908 of Keen, 1971*
Figure 5, 7A-D, 8C

* The opinion for a *B. rugosa* (Sowerby, 1835) synonymy is not discussed here.

Geographic range: Bahía de Panamá, Panama to Ecuador; Galapagos Islands.

Fossil occurrences: *Bursa calcipicta* has not been reported as a fossil.

Size: Adults range from 30 to 55 mm in length.



Figure 5. *Bursa calcipicta* Dall, 1908 33.9 mm (DBC)

Description: A relatively solid dorso-ventrally flattened light brown to gold shell, with a spiral sculpture consisting of four heavy regular beaded cords of alternating light and dark brown beads, the uppermost two beaded cords bearing two rows of beads and seven medium sized knobs per whorl, separated by one to two rows of fine light brown beads, a thickened apertural lip or varix twice per whorl with heavy denticles, a tubular posterior notch. aperture white with occasional light pink hues and the

inner lip has a medium to small glossy parietal shield with 5 to 6 lirae crossing the inner lip from the columella.

DIFFERENTIAL DIAGNOSIS

As discussed above, *Crossata californica* and *C. ventricosa* are here considered morphologically different species. The more important morphological differences between these two species are listed in Table 1 below, the most important of which include: (1) smaller maximum adult size in *C. ventricosa*, (2) much thinner shells in *C. ventricosa*, (3) the presence of only 6 or 7 large blunt shoulder knobs on the ultimate whorl in *C. californica* as opposed to 10 to 12 smaller shoulder nodes/knobs in *C. ventricosa*, and (4) the presence of distinct lirae

on the columella of *C. californica* which are generally absent on *C. ventricosa*.

In addition, the newly described *C. barbarajeanae* n. sp. can be differentiated from *C. californica* and *C. ventricosa* by having: (1) three nodes on the upper left of the aperture and the body whorl ornamented with fine cords and beads; (2) a rounded anterior siphonal gap; (3) a moderate lip forming a definite varix twice per whorl with denticles absent to weak on the inner portion of the outer lip; (4) weak lirae on the columella from near the posterior siphonal notch nearly to the anterior siphonal notch; and (5) the siphonal canal bends slightly to the left of the longitudinal axis.

<i>Crossata californica</i>	<i>Crossata ventricosa</i>	<i>Crossata barbarajeanae</i>
6-7 large blunt shoulder knobs	10-12 small shoulder nodes or sharp knobs	10-12 small shoulder nodes
Thickened lip forming heavy varix	Thin lip which does not form a definite varix	Moderately thick lip forming a definite varix
Heavy parietal shield	No parietal shield	Parietal shield in gerontic adults
Heavy denticles on lip	Weak to no denticles on lip	Denticles absent to weak on lip
Lirae on columella	Generally smooth columella	Weak lirae on columella
Spire height varies	Spire height consistent	Spire height consistent
Heavily corded / textured body whorl	Smooth body whorl	Fine cords and beads on body whorl
Siphonal canal bends slightly to the right	Siphonal canal bends slightly to the right	Siphonal canal bends slightly to the left

Table 1. Comparison of morphological differences between *Crossata* species.

A comparison of similarly-sized specimens of both *C. californica* (Figure 6 images A and B) and *C. ventricosa* (Figure 6 images C and D) illustrate these morphological differences. Several specimens of the deep water tropical eastern Pacific species *Bursa calcipicta* Dall, 1908, are illustrated in Figure 7 because Beu considered it synonymous with the eastern Pacific *Crossata* (Beu, 2010). A three-view comparison shows the important morphological differences for easy comparison (see Figure 8). *Bursa* species, including *B. calcipicta* are dorso-ventrally flattened (see apex view in Figure 8 image C) which easily separated them from the almost globose *Crossata* (see apex views in Figure 8, A and B) when looking down the apex. Further, *B. calcipicta* is generally significantly more ornamented and has a fine texture consisting of both beads and cords like all species in the genus *Bursa*, differentiating it from *Crossata*.

DISCUSSION

Modern Biogeography

Crossata californica is a warm temperate species found in the Californian Province, with the Golfo de California population previously known as *C. sonora* representing an isolated relic population in the Cortezian Subprovince of the Panamic Province. Neither *C. californica* nor *C. sonora* are otherwise found in the Panamic Province or the tropical eastern Pacific region. *Crossata ventricosa* is a warm temperate species found exclusively in the Peruvian Province, ranging only as far north as the Paíta District in northern Peru, just south of the Gulf of Guayaquil, Ecuador. There are no *Crossata* known in other parts of the Panamic Province, contrary to Beu's (2010) assertion. *Bursa calcipicta* is a morphologically distinct species from those of the genus *Crossata*.

Effects of Oceanographic Currents

Bursidae are known to have planktonic larva and to disperse over long distances (Scheltema, 1972). While oceanographic currents are known to disperse planktonic larvae, the major currents in the eastern Pacific Ocean are regarded as one-way dispersal corridors and also dispersal barriers (Zinsmeister & Emerson, 1979; Scheltema & Williams, 1983). The northern and southern Pacific Ocean gyres contain surface waters within the northern and southern hemispheres, respectively (Longhurst, 2007). Therefore, the northern and southern hemisphere oceanographic currents generally prevent planktonic larvae floating in the Californian Province and the Peruvian Province from reaching one another because they would have to travel across the warm water Equatorial current which, instead, takes them out to sea as it then turns sharply west out into the North Pacific Gyre of the Pacific Ocean. Similarly, the cool water Peruvian Current travels north into the warm water Equatorial Countercurrent and then turns west out into the South Pacific Gyre of the Pacific Ocean. The tropical waters of the Equatorial Countercurrent travel east towards the Isthmus of Panama forming local gyres in the warm waters of the tropical eastern Pacific region (See Figure 9). Given the direction of these surface currents, we conclude it is not likely for bursid planktonic larvae to cross between the southern North America and northern South America.

Paleobiogeography

Crossata californica has an extensive fossil record from southern California to Baja California, Mexico from the middle Pliocene to Pleistocene, while *C. ventricosa* has been reported, albeit we feel incorrectly, from the Miocene of Peru, as well as the Pliocene of Ecuador, Panama, and Peru, and Pleistocene of

Chile and Peru. These two fossil distributions are separated by over 3,500 km (the distance from La Paz, Baja California, Mexico to Panama), possibly more if the Panamanian occurrence is discounted. This huge gap in distribution in both fossil and modern specimens also argues that these two species are separate.

CONCLUSION

The three species *Crossata californica* (Hinds, 1843), *C. ventricosa* (Broderip, 1833), and *Bursa calcipicta* Dall, 1908 have been shown to be morphologically distinct, and *C. sonorana* is an isolated relic population of *C. californica*. Furthermore, the modern geographic separation of the species (~4,300 km), direction of currents carrying propagules, and distinct fossil records suggest there would be little likelihood of interdispersion of these taxa and further supporting the hypothesis that they are distinct species. A new undescribed *Crossata* species in shallow waters off central Peru, *C. barbarajeanae*, n. sp. is described. Finally, it is probable that *C. ventricosa* represents a complex of species and more study is needed of fossil forms, the nodulose northern offshore Peruvian island form, and the rare specimens of *Crossata* in Chile.

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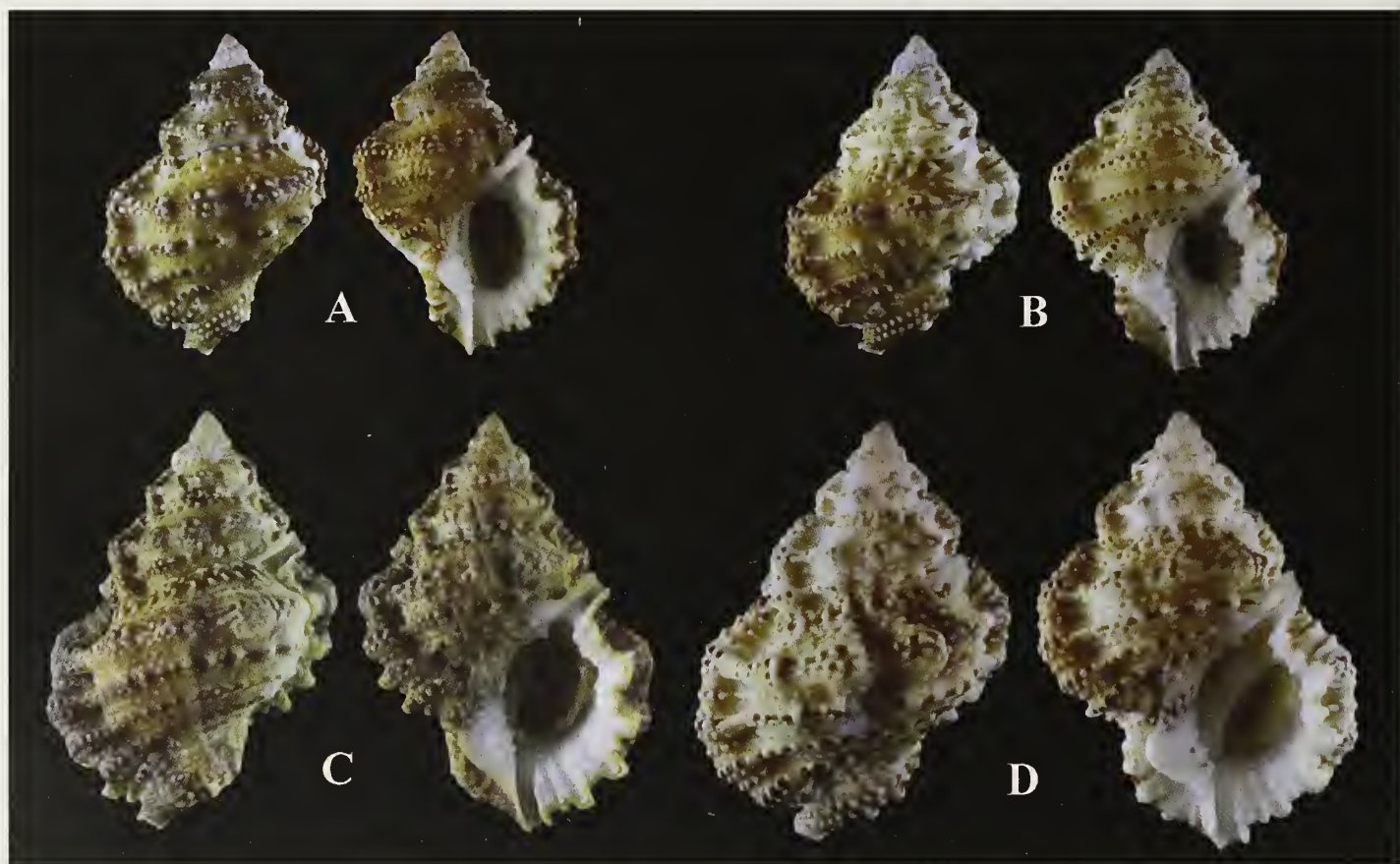


Figure 7. *Bursa calcupicta*. **A** = 33.8 mm, Bay of Chiriqui, Panama, 240 feet (PKC); **B** = 33.9 mm, Canal de Adentro Is., Panama, 120-140 feet (DBC); **C** = 46.1 mm, Venado Island, Panama (DBC); **D** = 45.0 mm, Canal de Afuca Is., Panama, 120-240 feet (DBC).

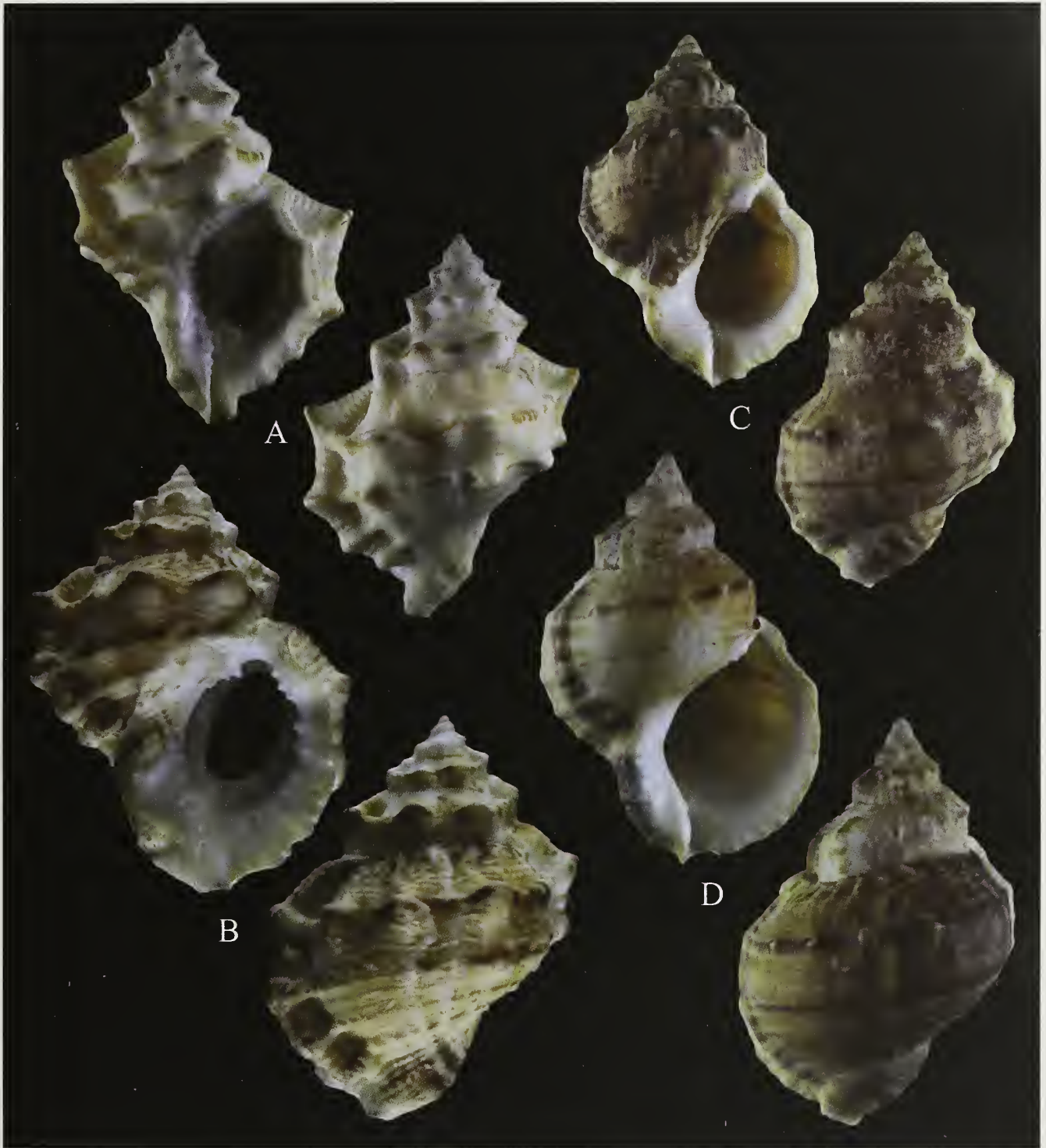


Figure 6. Comparison of *C. californica* (A, B) and *C. ventricosa* (C, D). **A** = 56.3 mm, Los Angeles Harbor, Los Angeles, California, USA; **B** = 59.6 mm, Los Angeles Harbor; **C** = 48.4 mm, Parachique, Piura, Peru; 63.1 mm, Parachique, Piura, Peru. All specimens from the PKC.

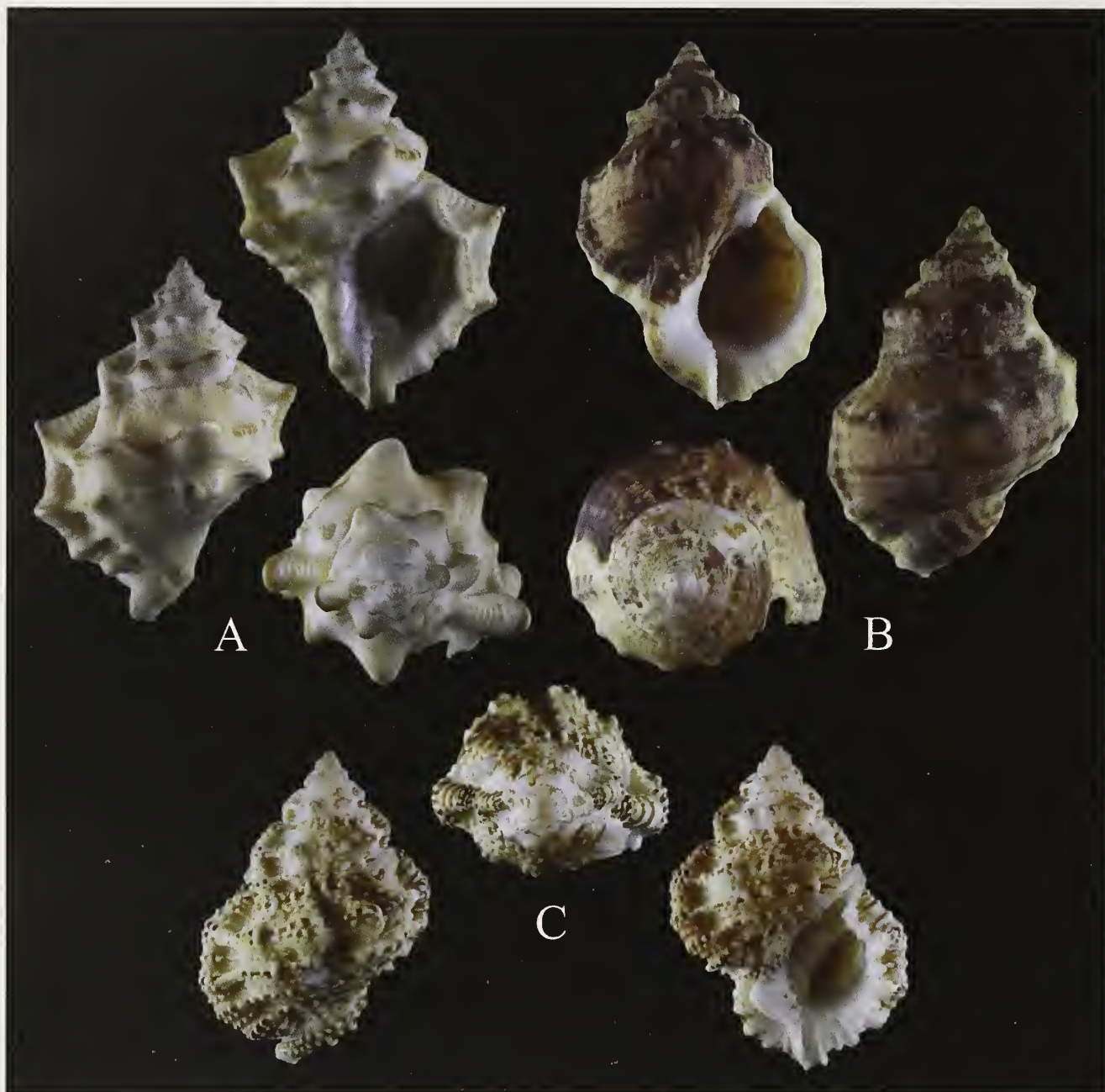


Figure 8. Three species comparison. **A** = *C. californica*, 56.3 mm, Los Angeles Harbor, Los Angeles, California USA (PKC); **B** = *C. ventricosa*, 48.4 mm, Parachique, Piura, Peru (PKC); **C** = *B. calcipicta*, 45.0 mm, Canal de Afuca Is., Panama (DBC).

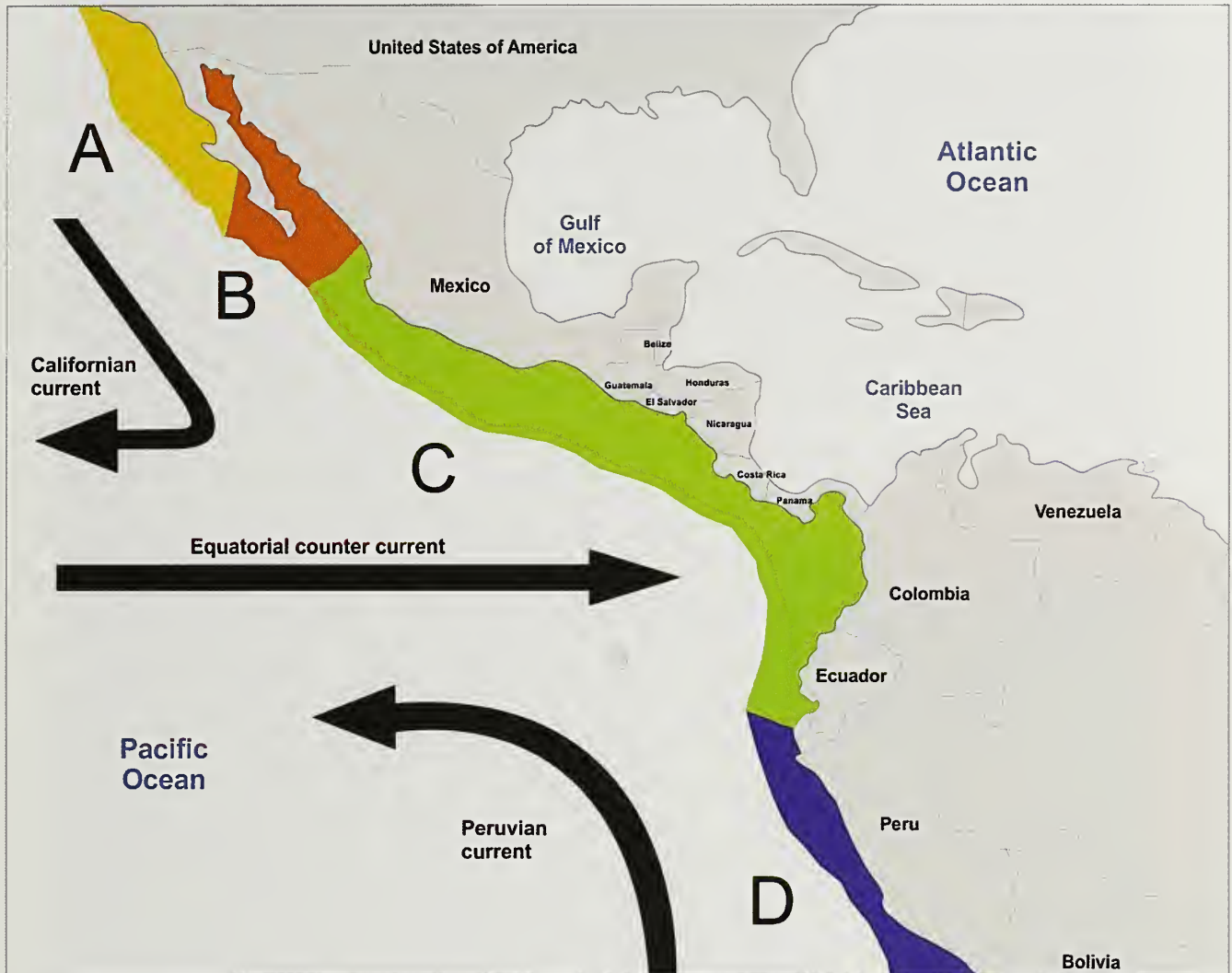


Figure 9. Map with biogeographical zones and oceanographic currents. A = Californian Province; B = Cortezian Subprovince of the Panamic Province; C = Panamic Province; D = Peruvian Province.

Figure 10. *Crossata ventricosa* (images A-H, J, K) and *C. barbarajeanae* n sp. (images I). A = 48.4 mm, Parachique, Piura, Peru (PKC); B = 61.2 mm, Parachique, Piura, Peru (DBC); C = 54.4 mm, Isla Lobos de Tierra, Peru, 100 m (LACM 66-138); D = 51.1 mm, Isla Lobos de Tierra, 100 m (LACM 66-138); E = 62.7 mm, Parachique, Piura, Peru (PKC); F = 62.8 mm, Parachique, Piura, Peru (PKC); G = 50.1 mm, Isla Los Chinos, Peru (SBMNH 470142); H = 69.7 mm, fossil specimen from Ancash, Huaynuna Midden, radiocarbon dated at 2,000 to 1,000 B.C., Casma Valley, Peru (SBMNH 467164); I = 48.0 mm, Bahia Independencia, Peru, at 16-18 m (LACM 35-24.1); J = 56.8 mm, Isla Macabí, Peru, 170 m (LACM 66-146); K = 63.1 mm, Parachique, Piura, Peru (PKC).

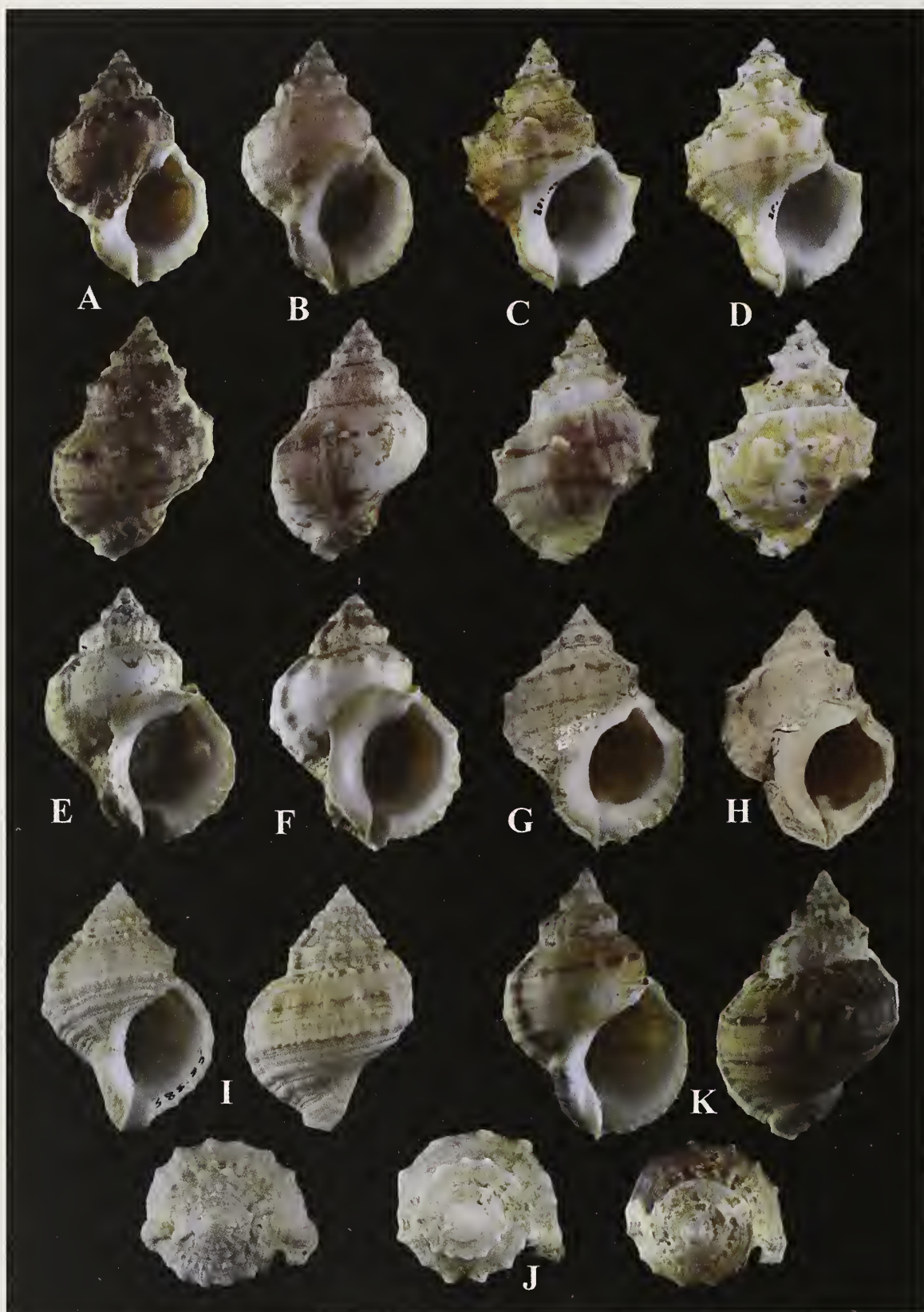


Figure 10. See legend above on bottom of page 194.

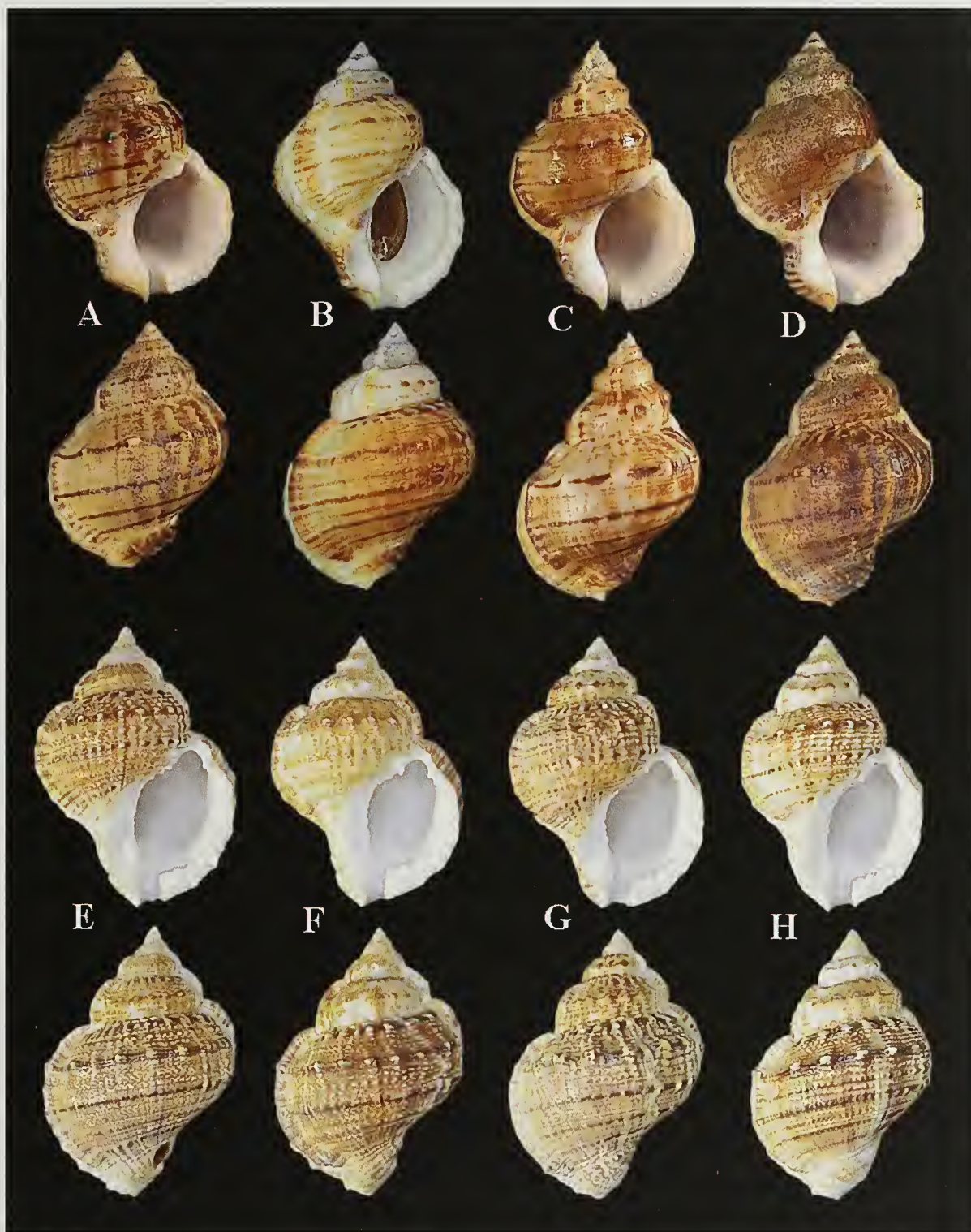


Figure 11. *Crossata ventricosa* (images A-D) and *C. barbarajeanae* n. sp. (images E-H). A = 60.4 mm; B = 55.1 mm; C = 65.4 mm; D = 62.8 mm; E = 47.8 mm; F = 49.0 mm; G = 50.1 mm; H = 54.0 mm. All images used with permission from Marcus Coltro (Femorale).

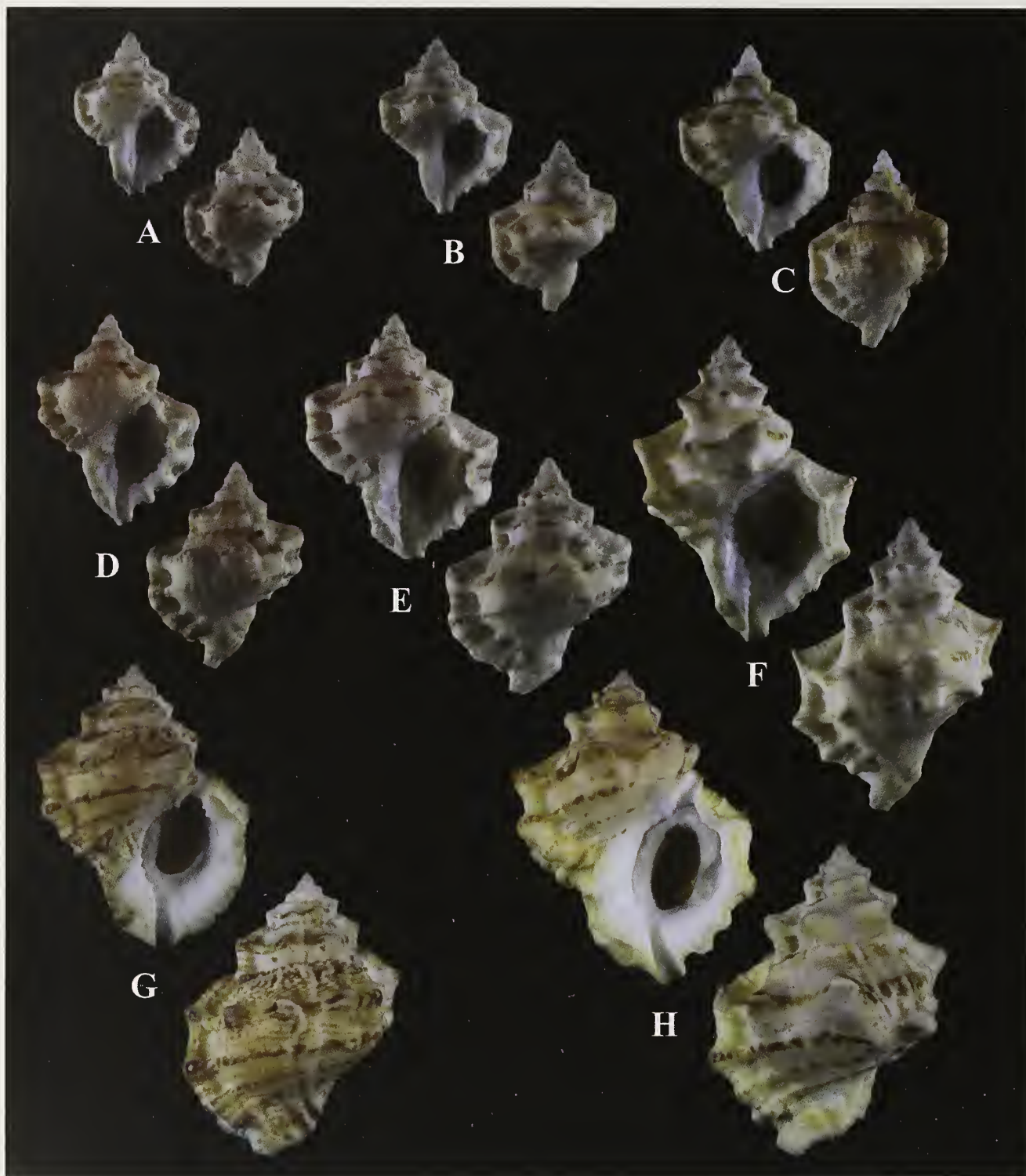


Figure 12. Growth series of juvenile and subadult *C. californica*. **A** = 24.6 mm; **B** = 26.4 mm; **C** = 31.0 mm; **D** = 33.1 mm; **E** = 38.0 mm; **F** = 56.3 mm; **G** = 59.6 mm; **H** = 65.3 mm. All specimens from the PKC, collected off Catalina Island, Los Angeles County, California, USA, at 50 to 70 feet.

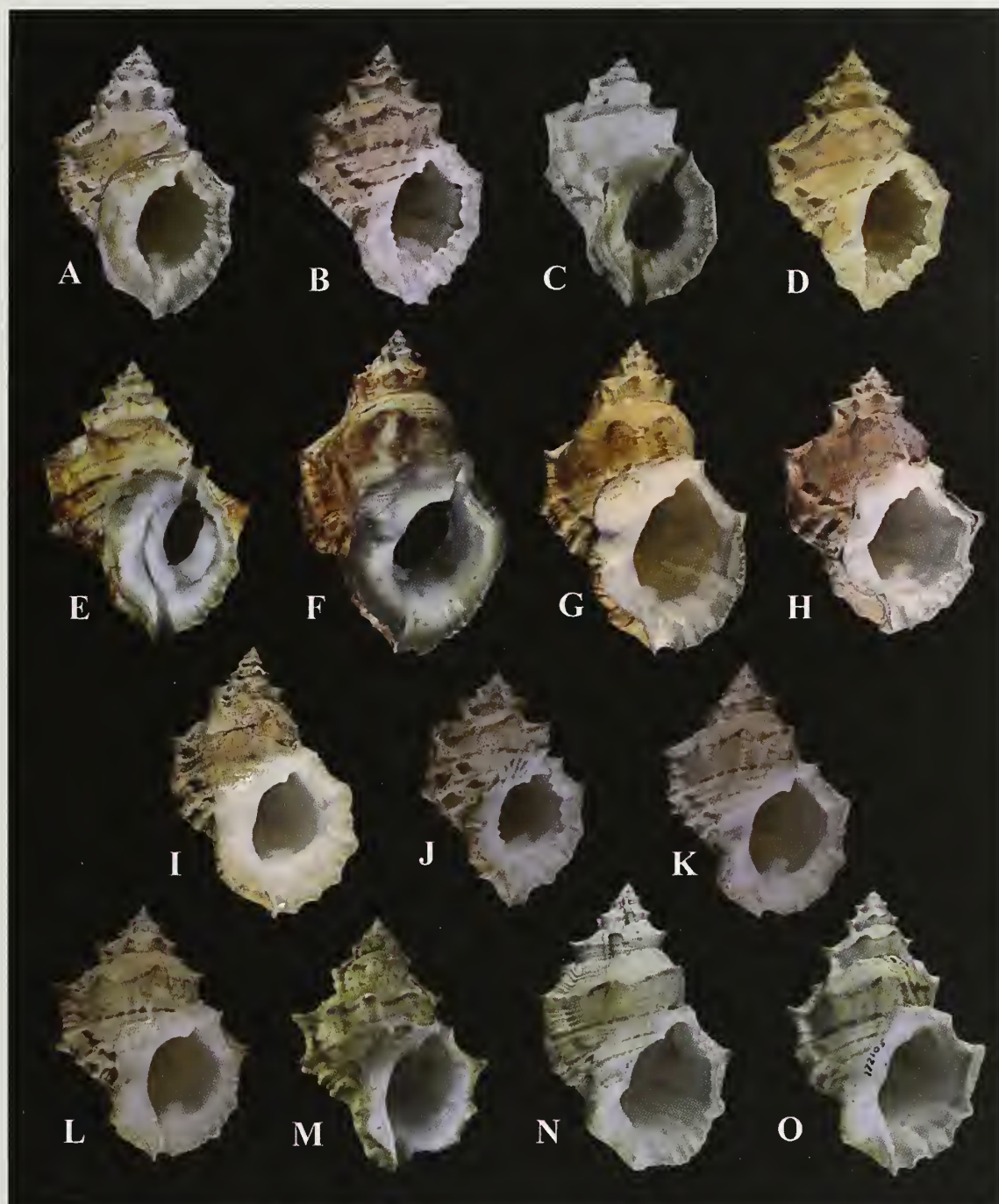


Figure 13. Adult specimens of *C. californica* from throughout its range. **A** = 94.0 mm, Santa Barbara, California, USA (SBMNH 470147); **B** = 77.3 mm, Point Concepcion, California, USA (SBMNH 138634); **C** = 74.6 mm, Santa Barbara Island, California, USA (DBC); **D** = 71.2 mm, San Diego, California, USA (SBMNH 470146); **E** = 97.7 mm, Redondo Beach, California, USA, at 100 feet (DBC); **F** = 169 mm, El Segundo, Los Angeles County, California, USA at 80 to 100 feet (PKC); **G** = 167 mm, Newport Bay, California, USA (SBMNH 470144); **H** = 102.4 mm, Newport Bay, California (SBMNH 470145); **I** = 116.0 mm, Laguna Guerrero Negro, Baja California, Mexico (SBMNH 131941); **J** = 72.4 mm, Isla Todos Santos, Baja California, Mexico (SBMNH 470141); **K** = 103.5 mm, S. of Tijuana, Baja California, Mexico (SBMNH 52874); Specimens identified as *C. sonoranana*: **L** = 91.1 mm, Guaymas, Sonora, Mexico (SBMNH 470207); **M** = 56.0 mm, Guaymas, Sonora, Mexico, trawled by shrimp boats (LACM 59-8); **N** = 111.3 mm, Guaymas, Sonora, Mexico, trawled by shrimp boats (LACM 145775); **O** = 103.1 mm, Punta San Antonio, Sonora, Mexico, 35 to 50 m, (LACM 172105).